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**DIELECTRIC SLIT DIE FOR IN-LINE
MONITORING OF LIQUIDS PROCESSING****CROSS REFERENCE TO RELATED
APPLICATIONS**

This application claims benefit of Provisional Patent Application Ser. No. 60/461,668 filed Apr. 11, 2003. This application uses the frammis vane disclosed in U.S. Pat. No. 5,208,544 granted May 4, 1993, U.S. Pat. No. 5,519,211 granted May 21, 1996, and U.S. Pat. No. 5,788,374 granted Aug. 4, 1998.

FEDERALLY SPONSORED RESEARCH

This invention was developed under sponsorship of the National Institute of Standards and Technology, Gaithersburg, Md.

**REFERENCE TO SEQUENCE LISTING, A
TABLE, OR COMPUTER PROGRAM**

Not Applicable

BACKGROUND OF INVENTION**1. Field of Invention**

This invention relates to multiple sensor monitoring of material properties of liquids during processing—particularly to the dielectric, optical and ultrasonics properties of molten polymer composites that are processed using an extruder machine.

2. Background of Invention

Many products are formulated by mixing liquid components together and by mixing liquids and solids together. Efficient manufacturing methods usually involve continuous processing whereby components are fed into a process line at one end, are mixed and then are transported by means of pipes and conveyor belts to post processing handling and examination. The properties of the final product are determined by recipes of component content, mixing time, temperature, pressure, chemistry and other process parameters. Often these recipes are complex and need to be monitored continuously in order to maintain product quality. The current practice for many processes is to examine product quality after the product has been made. In many cases, post-processing examination takes days or weeks to complete. On-line, real-time processing will eliminate the knowledge delay about the process, allow for immediate correction of process problems and be a sentry for the maintaining process integrity and product quality.

On-line process sensors of many types have been developed. These include ultrasonics, optics, rheological, and dielectric sensors. Applications of these sensors have involved installations of a single sensor with a focus on one material property. Multifunctional sensing with several sensors installed in an on-line chamber with multiple sensor ports is not currently practiced. For processing of complex liquids, such as polymer composites, foodstuffs, and mixtures in slurries, multiple sensing is needed because a single sensor, such as temperature or pressure, does not provide enough information to assess the condition and quality of the product. Each sensor has its assets and limitations whereas multiple sensors provide a collection of data, which, when integrated together, potentially yield a critical level of information.

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This invention not only addresses the need for more information about the processes and the material being processed, it also presents an improvement of the dielectric sensor design of McBrearty and Perusich, U.S. Pat. No. 5,208,544. The dielectric sensor of this invention is of the interdigitating electrode type, a concept that was developed by Senturia et al., U.S. Pat. No. 4,423,371, and subsequently commercialized by Micromet. Kranbuehl, U.S. Pat. No. 4,710,550, refined the measuring technique and the sensor so that the real and imaginary parts of the dielectric constant ϵ' and ϵ'' could be measured using a network analyzer. The Senturia et al. and Kranbuehl sensors were used primarily at low temperatures and in benign environments and are not suitable for measuring abrasive, molten plastics processed under flow at high temperatures and pressures. High temperature dielectric monitoring of highly viscous molten plastic was accomplished by McBrearty and Perusich who used a ceramic ring with interdigitating electrodes deposited and fired onto the inside of the ring. Dielectric properties of fluids flowing through the ring are measured. The design of the McBrearty and Perusich cell consists of the ceramic ring sandwiched between high temperature gaskets that are bolted between two stainless steel cylinders, and the entire housing is wrapped with temperature controlled heater bands. When connected to a process extruder or pump, the gaskets provide a leak-proof, flow-through cell for processing liquids under pressure.

The problem with the ceramic ring design is the limited extent to which the fringe field can interrogate the flowing liquid. For example, a ring with 12.7 mm inside diameter and having electrode separation $\lambda=0.5$ mm can interrogate only a thin shell near the electrodes that amounts to 15% of the cross section of the liquid flow stream. This is because the electric fringing field from the interdigitating electrodes decreases exponentially in intensity from the electrode surface with a characteristic length of $\lambda/3$. If λ is made larger in order to extend the fringe field, the sensitivity of the cell is diminished because of decreased capacitance. Sampling only 15% of the processed liquid is not satisfactory because it may not be representative of the total bulk properties.

Other problems with the ceramic ring design are the gaskets that are placed on either side of the ceramic ring in order to seal the unit and protect it from leaks. When processing polymers, these gaskets must perform at high temperatures for long periods of time. They are made of a specialty compound and they are expensive to replace as is needed during the normal course of operation.

It is the purpose of this invention to provide a common platform in a process line on which multiple sensors can be installed. Also, an integral part of this invention is an improved dielectric sensor. The dielectric sensor of this invention retains the robustness of the ceramic substrate used by McBrearty and Perusich while adding flexibility and new capabilities. The electroded ceramic substrate is used in an innovative slit design that incorporates complementary sensors and slit geometry while eliminating gaskets. Also, the design permits interchangeable ceramic substrates with different electrode patterns and electrode separation λ . The common platform is a slit through which processed liquids flow. The slit is made long enough to accommodate the sensors that access the liquid flowing therein. The slit defines a sample chamber of constant volume that is continuously being replenished by new material as the liquid flows into and out of the slit.

The advantages of this invention are: (a) the slit configuration that confines the flowing liquid to a thin ribbon for which a significant fraction of its cross section is intersected